A STATISTICAL ANALYSIS OF DEVIATIONS FROM TARGET COST IN NAVAIRSYSCOMHQ FIXED-PRICE INCENTIVE CONTRACTS DURING THE 1949 - 1965 TIME FRAME

Max Wayne Dixon

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

A STATISTICAL ANALYSIS OF DEVIATIONS FROM TARGET COST IN NAVAIRSYSCOMHQ FIXED-PRICE INCENTIVE CONTRACTS DURING THE 1949 - 1965 TIME FRAME

by

Max Wayne Dixon

Thesis Advisor: M.G. Sovereign

March 1973

A Statistical Analysis of Deviations from Target Cost in NAVAIRSYSCOMHQ Fixed-Price Incentive Contracts During the 1949 - 1965 Time Frame

by

Max Wayne Dixon
Commander, United States Navy
B.S., University of Oklahoma, 1955

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the
NAVAL POSTGRADUATE SCHOOL
March 1973

ABSTRACT

This paper statistically analyzes 15 years of NAVAIRSYSCOMHQ fixed-price incentive contract experience in the aircraft and missile procurement field. The relation of basic contract parameters to contract outcome is explored through regression and analysis of variance techniques.

The inferences arising from the statistical analysis are combined with other information to draw conclusions regarding incentive contracting. The most important of these is that there is no evidence that the negotiated sharing ratio has any influence on the contractor during the performance of the contract.

TABLE OF CONTENTS

I. INTRODUCTION

A. FIXED-PRICE INCENTIVE CONTRACTS - THEORY AND PRACTICE

1. Theory (from the government's viewpoint)

The basic parameters of a fixed-price incentive (FPI) contract are: target cost, range of incentive effectiveness (RIE), sharing ratio, ceiling price, and target profit.

Fixed-price incentive contracts are intended to be used for engineering development, management support, and production contracts in which the uncertainty of cost is too large to allow a firm fixed-price (FFP) contract. In terms of cost, this means approximately ± 15 to 20% variation about the negotiated target cost. If the range of cost uncertainty is larger than this, a cost reimbursable contract is indicated. If significantly smaller, a FFP contract should be considered.

FPI contracts are further subdivided into those involving a cost incentive alone, and those having schedule and/or performance incentives as well as a cost incentive. Both the cost incentive and multiple incentive contracts may have firm target(s), FPIF, or successive targets, FPIS. The contracts analyzed in this thesis are FPIF and FPIS contracts with cost incentives only.

Theory has it that the contractor will be influenced to effectively control costs and to make cost-associated trade-off decisions in a way favorable to his profit and therefore favorable to the government. The government's desires with regard to the cost outcome of a contract are communicated to the contractor in the form of the mutually agreed upon sharing ratio. This ratio, e.g., 80/20, says to the

contractor that his profit will increase $.20 for every dollar he saves in cost throughout the RIE, and vice versa. The RIE is chosen so as to encompass all likely contract cost outcomes including the most likely outcome (the target cost). Insurance against a massive cost overrun is provided by another parameter, ceiling price. This figure tells the contractor the maximum the government will pay, cost + profit, for completion of the contract no matter what the cost outcome. It should be noted that for a cost outcome greater than the ceiling price, the contractor's profit is negative, i.e., a loss. Also for a range of cost outcomes less than the ceiling price, each dollar of extra cost comes out of the contractor's profit directly. In effect, the sharing ratio in this range is 0/100. This range is bounded by the point of total assumption (PTA) on the lower cost side, and unbounded on the higher cost side.

The target profit is established upon, at least in part, the degree of financial risk accepted by the contractor as determined by the type of contract and where applicable, the sharing ratio. That is, an FPI contract with a 50/50 sharing ratio is assumed to be more financially risky for the contractor than one containing an 80/20 sharing ratio. Further, a FFP contract is considered more financially risky than a cost plus incentive fee (CPIF) contract.

The underlying assumptions of incentive contracting are:

a. That the contractor seeks to maximize profit on each contract.

b. That the most likely, optimistic, and pessimistic cost outcomes are established free of bias and with some degree of accuracy.

c. That the contractor can control the cost of performance significantly during performance.

2. Practice

In practice there is reason to believe that each of the previous assumptions is subject to considerable doubt.

a. Profit maximization - Contractors appear willing to sacrifice profit on a particular contract to other goals such as long-term profit or simply survival.

b. The most likely cost outcome, target cost, is subject to a number of types of bias. For example, a contractor may be willing to accept an unrealistically low target cost if the industry is characterized by overcapacity and high competition. Similarly, the government may accept an excessively optimistic view of future cost outcome if the competition for available funds is high within the government. The target cost negotiated in a sole-source situation may be unrealistically high if the government has no good basis of comparison. In which case the contractor can increase his profit by "accepting" an FFP contract and gain a 0/100 share of the underrun and a higher target profit to boot [ref. 1]. And lastly, it is not currently possible to predict future costs with any reasonable degree of accuracy on a technically complex item which has not been produced before. Further, contract negotiation is an adversary proceeding in which each side does its best to protect its own interests. Such a proceeding cannot be characterized as a cooperative search for truth in the establishment of contract target cost. For example, the contractor may raise his negotiation objective with regard to target cost to compensate for the risk of loss imposed by the existence and value of the sharing ratio. The selection of three costs, pessimistic, most likely and optimistic, does not decrease the uncertainty in the cost estimate unless valid information is available upon which to base the cost probability distribution

inherent in the three costs. In the author's opinion, such information is generally not available and the seeming decrease in cost uncertainty is illusory.

c. Contractor control of cost during performance - In order to control costs during performance, the contractor must be able to predict cost outcomes sufficiently in advance and take effective action. Attempts by a contractor to make significant improvements in efficiency during performance of a contract may result in managerial disutilities and may increase rather than decrease costs [ref. 2].

B. OBJECTIVE OF THE ANALYSIS

The objective of the analysis presented subsequently was to draw statistical inferences as to the readily quantifiable contract parameters which have a statistically significant effect on contract outcome in percent deviation from target cost. The chosen parameters are ones that are measurable and known at the time the contract is signed or shortly thereafter. These parameters are target fee, sharing ratio, ceiling price, target cost, scheduled length of performance, number of articles procured, the number of aircraft and missile contracts initiated that year, and the year performance started. As originally scheduled contract performance was not available, actual length of performance was substituted therefor.

A further objective of this analysis was to generate, if possible, a model which explained a significant amount of the variation from contract to contract in the outcome percent deviation from target cost using the contract parameters listed below. The utility of such a model is obvious in the predictive sense.

Percent deviation from target cost was determined to be the dependent variable for most of this analysis because of the three measurements of contract outcome, cost, schedule, and performance, cost is the one which is most readily measured and publicized. Further, the adverse effects of system performance degradation from initial estimates and schedule slides are difficult to identify and measure.

The following factors in contract outcome may have been important but were unavailable:

1. Initial contractor estimates of contract cost.

2. Initial governmental estimates of what the contract should cost.

3. The degree of technical risk involved in the article purchased.

4. The changes in contract cost generated by schedule changes, engineering change orders, governmental failures to deliver government furnished data, material and equipment on time.

5. Renegotiation of fees.

These unmeasured variables and others can be expected to result in a rather large random variation in contract outcome as regards deviation from target cost. If this variation is indeed random rather than systematic and is distributed approximately normally, useful inferences can be drawn from regressions and etc., that do not explain a large part of the variation.

C. HYPOTHESES

In the opinion of the author, the following hypotheses could reasonably be made regarding the effects of the measured contract parameters listed in B. on percent deviation from target cost:

1. Length of performance of the contract - it might reasonably be expected that cost deviation would increase (that is positively or in the direction of cost overrun) as the length of performance increases. This might be true because of the difficulty of projecting costs into the far future, the general inflationary trend experienced, and the increased opportunity afforded to make changes.

2. Target profit - Expectation would be that larger target profits would be associated with larger positive deviations from target cost because theoretically target profits are established on the basis of the risk involved in the contract and other factors.

3. Sharing ratio - Actual costs moved in the negative direction (toward cost underrun). The theory of cost incentive contracting is that the stimulus provided by an increased sharing ratio will cause the contractor to at least attempt to operate more efficiently. Of course, it may also stimulate him to negotiate for a higher target profit and/or a higher target cost.

4. Ceiling price - A higher ceiling price would be expected to result in less attention to incurred cost and thereby tend to influence deviation from target cost in a positive direction. All other things being equal, a higher ceiling price (in terms of percent of target cost) moves the point of total assumption further from the target cost. If the actual cost of performance exceeds the point of total assumption, each dollar of additional cost comes directly from the contractor's profit on the contract. In effect the contract becomes a firm fixed-price contract (100% sharing ratio) beyond the point of total assumption.

5. Target cost - The author does not care to hypothesize on this variable's effect on deviation from target cost. As the dependent variable in this analysis is the ratio of cost deviation to target cost

expressed in percent, all other things being equal, increases in target cost would result in a decrease in the dependent variable. On the other hand, to the degree that an increased target cost may reflect increased complexity, increased time of performance, etc., an increase in target cost might result in a positive change in deviation from target cost. Notwithstanding the clouding effect that choosing such a ratio for the dependent variable has on this independent variable, target cost, it was considered necessary to permit meaningful comparison among contracts which vary in target cost from under $1 million to over $200 million.

6. Number of articles procured - Deviation from target cost was expected to vary negatively as the number of articles procured, i.e., the larger the number of articles procured the less positive or more negative cost deviation was expected to be. The larger the number of articles procured under a particular contract the less the developmental aspects of a basically production contract should effect actual total cost. Further, larger production quantities would be expected to result in operation on more favorable portions of the learning curve for more of the contract performance.

7. Number of Navy aircraft and missile contracts signed the same year as a particular contract - It was expected that the larger the number of contracts signed, the less positive or more negative deviation from target cost would be. The diversion of facilities and personnel from defense to non-defense work is at best a painful and expensive alternative for major aerospace contractors. To a lesser degree the diversion from aircraft and missile production to other defense production is also painful and expensive. In some cases, e.g., Grumman, the diversion from Navy aircraft and missile work to similar

work for the Air Force or Army is not particularly attractive. These things are considered true irrespective of the size of the contractor's investment in aircraft and missile production facilities because of the psychological barrier to entering a field where the rules of engagement are largely unknown from a field in which one is expert. Further, a Rand Corporation report indicates that at the same time that the numbers of Navy aircraft and missile contracts were decreasing a like phenomena obtained in Air Force contracts [ref. 3] at least as regards total contract dollar value. In sum then, exit from the Navy aircraft and missile market and entry into another was not easy so the effect of a decreasing number of available contracts should be a tendency toward a more optimistic view on the contractor's part of estimated costs particularly in competitively negotiated procurements. If such were the case, the final result could be expected to be a positive change in deviation from target cost.

8. The year the contract was signed - The author's intuitive expectation was that contracts signed in the later years of the period covered by the data would show more positive deviation from target cost. The steadily increasing publicity concerning cost overruns during the period would indicate that that was the case. The other variables' independency of the year the contract was signed is certainly open to question. Any of the other independent variables may prove to be time dependent which will reduce this variable's usefulness as a predictor. Other than as a reflection of changing contractor and/or government policy, the author is hard pressed to explain a systematic variation of deviation from target cost with time if such, in fact, exists.

II. DESCRIPTION OF DATA

A. SOURCE

The raw data were obtained by the author through the good offices of Mr. M. E. Biciocchi, Naval Material Command, code 022B.

B. NATURE OF THE DATA

1. Form

The data encompass all Naval aircraft and missile fixed-price incentive contracts completed, redetermined and approved by ONM during the period 1954 through 1966. The information listed in the data for each contract is:

a. Contract period

b. Contract number

c. Contractor

d. Nomenclature and number of items procured

e. Negotiated target cost

f. Final cost

g. Percent deviation from target cost

h. Incentive profit pattern in terms of:

  (1) Target profit

  (2) Sharing ratio

  (3) Ceiling price in percent of target cost

i. Final profit rate

j. Target profit

k. Final profit

2. Quantity of Data

The data contained 178 individual data points (contracts) from which field one was deleted because it dealt with the procurement of spare parts. Thus the population analyzed contained 177 contracts.

3. Period

Although the earliest contract in the data was signed in 1949 and the latest in 1963, it was considered that results useful in the future could be obtained therefrom. It would appear that future Navy procurement will more closely resemble that of the 1949 through 1963 time frame than the later McNamara era. It is the author's opinion that data taken from Mr. McNamara's total package procurement contracts would be of little value in attempting to draw inferences useful in the future when total package procurement is so vigorously eschewed.

C. DATA SUMMARY

1. Variable Means and Standard Deviations

Variable	Mean	Standard Deviation
Contract period (months)	60.5	19.3
Target profit (percent)	9.0	0.8
Sharing ratio (percent)	19.3	8.1
Ceiling price (percent)	123.2	5.1
Target cost (millions of dollars)	46.5	46.6
Number of articles procured	377	1248
Number of contracts signed per year	17	8
Deviation from target cost (percent)	-1.3	9.1

2. Comment on Variables

Although target profit is intended to vary with sharing ratio and other factors, in fact, approximately 68% of negotiated target

profits fell within less than one percent of the mean, 9%. This is surprising considering that the data covers a period of 15 years and a multitude of different procurements. It is tempting to suspect that target profit was close to a "magic number" with a mode of, say, 10%.

Ceiling price seems to fall rather neatly into the same category since the standard deviation is only five percent, and the mean, 123.2%, falls close to the mode, 125%.

3. Miscellaneous

The data includes purchases of combat and utility piloted airplanes, helicopters, blimps, drones, missiles, and airborne electronic equipment, e.g., radars. Twenty-three contractors are represented in the data. Of these, thirteen completed five or more contracts during the period. Six completed 10 or more contracts:

Ling-Temco-Vought (10 contracts)

Convair (10 contracts)

North American (13 contracts)

Douglas (23 contracts)

Grumman (24 contracts)

Lockheed (30 contracts)

On the contracts contained in the data, the Navy spent a total of \$ 8,885,589,000 of which \$ 8,134,340,000 were actual costs and \$ 751,249,000 actual profits. The average profit rate realized by the contractors was 9.2% of actual costs. During the period of the data, defense contracting, at least in this area, was an extremely profitable business even on the basis of sales. Return on investment figures would, of course, be even more attractive given the large amount of government owned facilities involved.

III. DATA ANALYSIS METHODS

A. LINEAR REGRESSION

1. Theory

Linear regression is a technique for making statements as to the degree of linear association between a criterion (dependent) and one or more predictor (independent) variables using the method of least squares. If evidence exists that suggests that the form of one or more independent variables should be of a higher degree, the original variables can be transgenerated to fit the linear assumption. The following assumptions are required in order to make probability statements about single or multiple linear regression:

a. That the relation between the expected value of the dependent variable (Y) and an independent variable (X) (or X^2 or $X^{1.3}$ or $X_1 \cdot X_2$ or X_1/X_2, etc., as previously mentioned) is linear.

b. That the error distribution is constant or homosceda ic.

c. That no variable which is apt to effect the dependent variable is excluded from the equation. This assumption is not impo: tant if the objective is forecasting.

d. That the differences between actual and estimated values of the dependent variable are normally distributed.

Though these assumptions are not always justified in this analysis, the insight to be gained from the linear regression is considered more important than precision.

2. Computer Code

The computer code used by the author for single and multiple linear regressions on the dependent variable was a part of the

International Business Machines Scientific Subroutine Package labelled REGRE. REGRE provides the following output for a particular regression:

a. A list of the dependent and independent variables included in the regression along with their means and standard deviations.

b. A simple correlation coefficient (r) for each independent variable which measures the degree to which variation in the dependent variable is linearly associated with variation in that independent variable. The simple correlation coefficient has a range from -1 to +1. Larger absolute values of the simple correlation coefficient indicate greater correlation while the sign indicates dependent variable variation in the same direction as the independent variable (+) or opposite to the independent variable (-).

c. The regression coefficient determined for each independent variable included in the regression ($b_1, b_2, \cdots, b_n$).

d. The standard error for each regression coefficient.

e. A measure of assurance that each regression coefficient is not statistically different from zero by use of the Student t statistic.

f. The value of the estimated dependent variable when the independent variables all equal zero (intercept).

g. The multiple correlation coefficient (R) from which the coefficient of multiple determination (R^2) may be obtained. R^2 ranges between 0 and 1 and represents the proportion of variation in the dependent variable that is accounted for by the net linear association of all of the independent variables included in the regression.

h. The standard error of estimate for the regression.

i. The degrees of freedom, sums of squares and mean squares associated with an analysis of variance for the regression and the

resulting Snedecor F statistic which infers the degree of assurance one may place in the fact that there is a systematic linear variation of the dependent variable with the included independent variables.

3. Rationale for Linear Regression

Although there is some support in the literature for a non-linear association of sharing ratio with deviation from target cost, the analysis is based on theories of risk aversion or easy exit from the defense market [ref. 4] which the author believes to be unrealistic. The author's opinion on the ease of exit from or entry into the defense market has already been stated in section I.C.7. In the author's opinion contractors are willing to accept a high risk of decreased or no profits to buy into a contract because follow-on contracts can be expected to be profitable. Contractors may also expect to improve their profit position through change orders (constructive or otherwise) during performance of the contract. A toughening government position on this sort of activity is a creature of the late 1960's and 1970's.

In short then, the author has chosen to confine himself, except in one case, to linear combinations of first-degree variables.

4. Stepwise Linear Regression

The form of multiple linear regression actually used by the author in the final analysis was stepwise regression. In stepwise regression, a sequence of multiple linear regressions are computed in a stepwise manner. At each step one independent variable is added to the regression equation on the basis of which of the remaining (unused) independent variables makes the greatest reduction in the error sum of squares. Equivalently, the variable added next is the variable which has the highest partial correlation with the dependent variable partialed

on the variables which have already been added; and equivalently it is the variable which, if it were added, would have the highest F value.

The computer code used for stepwise regression was BMDO2R developed by the Health Sciences Computing Facility at the University of California at Los Angeles. BMDO2R also produces a correlation matrix of each independent variable with all of the other independent variables considered for the regression equation. It also outputs a plot of residuals versus computed values of the dependent variable for examination for systematic trends, if any. The intercepts, Multiple R, standard error of estimate, and analysis of variance are produced after each step as in the linear regression code discussed previously, REGRE.

5. <u>Linear Regressions on Segments of the Data</u>

Linear regressions were performed for each contractor having five or more contracts during the period relating the year the contract was signed and the number of contracts signed that year to predict values of percent deviation from target cost.

The plot of percent deviation from target cost versus the year of the contract in the case of Lockheed revealed a sine wave pattern. A special linear regression was done on the Lockheed data using the cosine of a function of the year signed as the independent variable.

6. <u>Target Profit as a Dependent Variable</u>

To investigate the degree to which target profit depends upon the negotiated sharing ratio and length of contract, linear regressions were performed using target profit as the dependent variable and sharing ratio and length of contract respectively as independent variables.

7. <u>Regression Independent Variables</u>

The following variables available in the data were considered to be suitable for linear regression:

Symbol	Description
X_1	Length of contract period in months
X_2	Actual cost deviation from target cost in percent of target cost (dependent variable)
X_3	Target profit in percent of target cost
X_4	Sharing ratio in terms of contractor's share of the cost risk in percent
X_5	Ceiling price in percent of target cost
X_6	Target cost in millions of dollars
X_7	The number of articles procured
X_8	The number of Navy aircraft and missile contracts signed the same year as a particular contract
X_9	The year the contract was signed, coded by subtracting 1948
X_{10}	The ratio of the target cost and the number of articles procured in millions of dollars/article
X_{11}	The product of the target cost and the number of articles procured in article-millions of dollars

B. ANALYSIS OF VARIANCE

1. Theory

Analysis of variance is a way of dividing total variation in experimental data into components that can be assigned to specific sources. The objective is to test the statistical significance of

differences among average responses caused by some variable after making allowances for other variables. The label, analysis of variance, is appropriate because if the mean responses of the test objects are different among groups, then the variance among groups will exceed the independently computed within-group variance.

Analysis of variance has some rather severe drawbacks when applied to nonexperimental or observational data. First, when some classifications of the data contain one or less data point, a within-group variance can not be computed and the mathematical rigor of the analysis is severely reduced. This problem can be ameliorated by pooling of some treatments such that several data points fall in each classification. Second, the basic analysis does not provide information as to which treatment(s) were statistically different. The F test performed only indicates that one or some of the populations were actually different. Further investigation as to which treatment or treatments were actually different from the others can be conducted using the Scheffé comparison test which will be discussed later. Third, gradual changes in the means in the data through the treatments will be discovered in the analysis of variance but not be isolatable by the subsequent comparison test. In this case, the effect of the particular variable may be investigated through regression or a combination of regression and analysis of variance, analysis of covariance.

The basic assumptions of the parametric analysis of variance are:

a. That the observations are independently drawn from normally distributed populations. This assumption makes the analysis parametric.

b. That the populations all have the same variance.

c. That the means in the normally distributed populations are linear combinations of "effects" due to rows and columns, i.e., that the effects on the dependent variable of the factors included are additive.

2. Computer Code

The computer code used by the author for one-way analysis of variance was BMD01V developed by the Health Sciences Computing Facility at the University of California at Los Angeles. BMD01V outputs:

a. Treatment means and standard deviations

b. Within-groups, between-groups, and total sums of squares.

c. Within-groups, between-groups, and total degrees of freedom.

d. Within-groups and between-groups mean squares.

e. F ratio for the test of the hypothesis H_0: $\text{mean}_1 = \text{mean}_2 = \cdots = \text{mean}_k$.

More than one-way analyses of variance were not used by the author because of the prohibitive severity of the empty cell or single observation cell problem which arises in multi-way analyses. For example, a three-way ANOVA on contractor (there are 23 of them), year (15 of them) and item (7 of them) would contain 23 X 15 X 7 = 2415 cells. Since there are 177 data points, at the least, 2415 - 177 = 2238 would be empty, and the majority of the filled cells would contain only one data point.

3. Rationale for Use

The author's rationale for employing a parametric analysis of variance is essentially that stated under linear regression.

4. Variables

The factors (variables) chosen for one-way analysis of variance were:

a. Factor one - contractor with the individual contractors being the levels of that factor (contractors that had more than one contract during the period).

b. Factor two - type of equipment procured using the following levels:

(1) Utility airplanes

(2) Combat airplanes

(3) Missiles

(4) Blimps

(5) Helicopters

(6) Pilotless airplanes (drones)

(7) Airborne avionic equipment

C. SCHEFFÉ COMPARISON TEST

1. Theory

If an analysis of variance has resulted in the rejection of the equal mean hypothesis, the Scheffé comparison test (S-test) may be used to compare levels two at a time (or more) to identify which levels were significantly different from others, if any. Again, a gradual change over the levels will not be identified.

2. Computer Code

Because a preprogrammed routine for the S-test was not found available by the author, a computer code was written by the author. That code is contained in Appendix A. No attempt was made to write a generally applicable code. The program contained in Appendix A is tailored to fit the data being examined in this thesis and to use the level means, etc., available from the preceeding analysis of variance.

3. Application

Analyses of variance and Scheffé comparisons were conducted upon the entire data and some individual contractor data. Individual contractors so treated were those that completed enough contracts during the period to make such an analysis feasible. Specifically, the Lockheed, Grumman and Douglas data, classified by the year the contract was signed, and pooled as necessary to have at least two observations per group, were so analyzed.

IV. RESULTS OF DATA ANALYSIS

A. LINEAR REGRESSIONS

1. All Contractors

a. Stepwise Linear Regression

The stepwise linear regression discussed in paragraph II.A.4. resulted in the following multiple linear regression equation:

$$\text{Percent deviation from target cost} = -42.4 + 0.128X_1 - 1.68X_3 + 0.397X_5 - 0.297X_8 + 0.823X_9 - 0.00004X_{11}$$

The independent variables entered the equation in the order X_8, X_3, X_1, X_{11}, X_9, X_5. When the stepwise regression routine terminated the computation, the lowest F-ratio for a variable included in the equation was 7.5345. The highest F-ratio for a variable not included was 1.1953. When the routine was forced to start with each of the variables other than X_8, the resulting equation was the same unless the routine was forced to include a variable which would not have been otherwise included because of low F-ratio.

The linear regression variables are included here again to ease interpretation of the results:

Symbol	Description
X_1	Length of contract period in months
X_2	Realized deviation from target cost in percent of target cost (dependent variable)
X_3	Target profit in percent of target cost
X_4	Sharing ratio in terms of the contractor's share of the overrun or underrun
X_5	Ceiling price in percent of target cost

Symbol	Description
X_6	Target cost in millions of dollars
X_7	The number of articles procured
X_8	The number of Navy aircraft and missile contracts signed the same year as a particular contract
X_9	The year the contract was signed, coded by subtracting 1948
X_{10}	The ratio of the target cost and the number of articles procured in millions of dollars/article
X_{11}	The product of the target cost and the number of articles procured in article-millions of dollars

The F-ratio for the whole regression is 9.559 which indicates that the level of the test is higher than 0.005. That is, the probability that all of the regression coefficients are not zero is at least 0.995.

The F-ratio test for each regression coefficient in the equation above along with the associated probabilities are listed below:

Regression Coefficient	Value	F-ratio	Probability $b_i \neq 0$
b_1	0.128	12.70	0.995
b_3	-1.680	4.67	0.950
b_5	0.397	8.37	0.995
b_8	-.297	7.03	0.990
b_9	0.823	9.51	0.995
b_{11}	-.00004	7.53	0.990

The additional variables, X_{10} and X_{11}, were formed from two of the original variables, X_6 and X_7, which were not significant in the regression individually and were not closely correlated with each other as determined from the correlation matrix. The correlation of X_6 with X_7 was -.023.

$$X_{10} = X_6/X_7$$
$$X_{11} = X_6 \cdot X_7$$

The variables considered in the regression but not included were:

Regression Coefficient	F-ratio	Probability $b_i \neq 0$
b_4	0.80	less than 0.75
b_6	0.68	" " 0.75
b_7	0.38	" " 0.50
b_{10}	0.90	" " 0.75

The value of the multiple correlation coefficient (R) fo. this regression was 0.502. Therefore, the value of the coefficient multiple determination (R^2) for this regression was 0.252, i.e., approximately 25% for the variation in the dependent variable (percent deviation from target cost) is accounted for by the net linear association of independent variables, X_1, X_3, X_5, X_8, X_9 and X_{11}.

The standard error of estimate for the regression is $\pm$ 7.97 percent deviation from target cost. That is, approximately 68% of the estimates from the regression equation fall within $\pm$ 7.97 of the observed values of percent deviation from target cost whose mean was -1.25.

b. Percent Deviation from Target Cost Versus Year Contract Signed

A linear regression was performed relating the percent deviation from target cost to the contract year alone to get a historical perspective. The resulting equation was:

$$\% \text{ deviation from target cost} = -4.94 + 0.573X_9$$

The computed t-value for this regression was 3.28 or equivalently the F-ratio was 10.73, both meaning in this case that the probability that the value of the regression coefficient was actually zero was .005. The coefficient of correlation was .240 and the proportion of variation in the dependent variable accounted for is approximately 0.06. The standard error of estimate was $\pm$ 8.82.

c. Target Profit (X_3) Versus Other Contract Parameters

A series of single linear regressions were conducted to determine if any other contract parameter known to both sides during negotiations was a good predictor of the negotiated target profit. The results of these regressions were as follows:

Independent Variable	Intercept	b_i	R	R^2	Standard Error of Est.	Probability $b_i \neq 0$
X_1	9.60	-.0102	.232	.05	0.828	0.995
X_4	8.37	.0320	.304	.09	0.811	0.995
X_7	8.92	.00017	.254	.06	0.823	0.995
X_6	9.07	-.00182	.100	.01	0.847	0.750
X_5	15.51	-.0529	.319	.10	0.807	0.995

A multiple linear regression was performed using dependent variables X_1, X_4, X_5 and X_7. The results of this multiple linear regression were:

Independent Variable	b_i	t-value	Probability $b_i \neq 0$
X_1	-.00437	1.36	0.900
X_4	.0182	2.30	0.975
X_5	-.0395	3.31	0.995
X_7	.0001	2.08	0.975

Intercept	13.37
R	0.437
R^2	0.19
Standard Error of Estimate	0.773
F-value	8.06
Probability that $b_i \neq 0$	0.995

Variable X_6 (Target Cost) was not included in the final regression equation because the t-value (.014) did not have a high enough probability that the regression coefficient (b_6) was not equal to zero (less than 0.75).

2. Individual Contractors

a. Grumman

The plot of percent deviation from target cost versus year of the contract for Grumman's contracts contained in Figure 1 displayed an apparent annual trend. This apparent trend suggested a linear regression on percent deviation using the year the contract was signed (X_9) as the independent variable. The results of this regression were:

Intercept	-12.34
Regression Coefficient (b_9)	1.57
Correlation Coefficient (R)	0.631
Determination Coefficient (R^2)	0.40

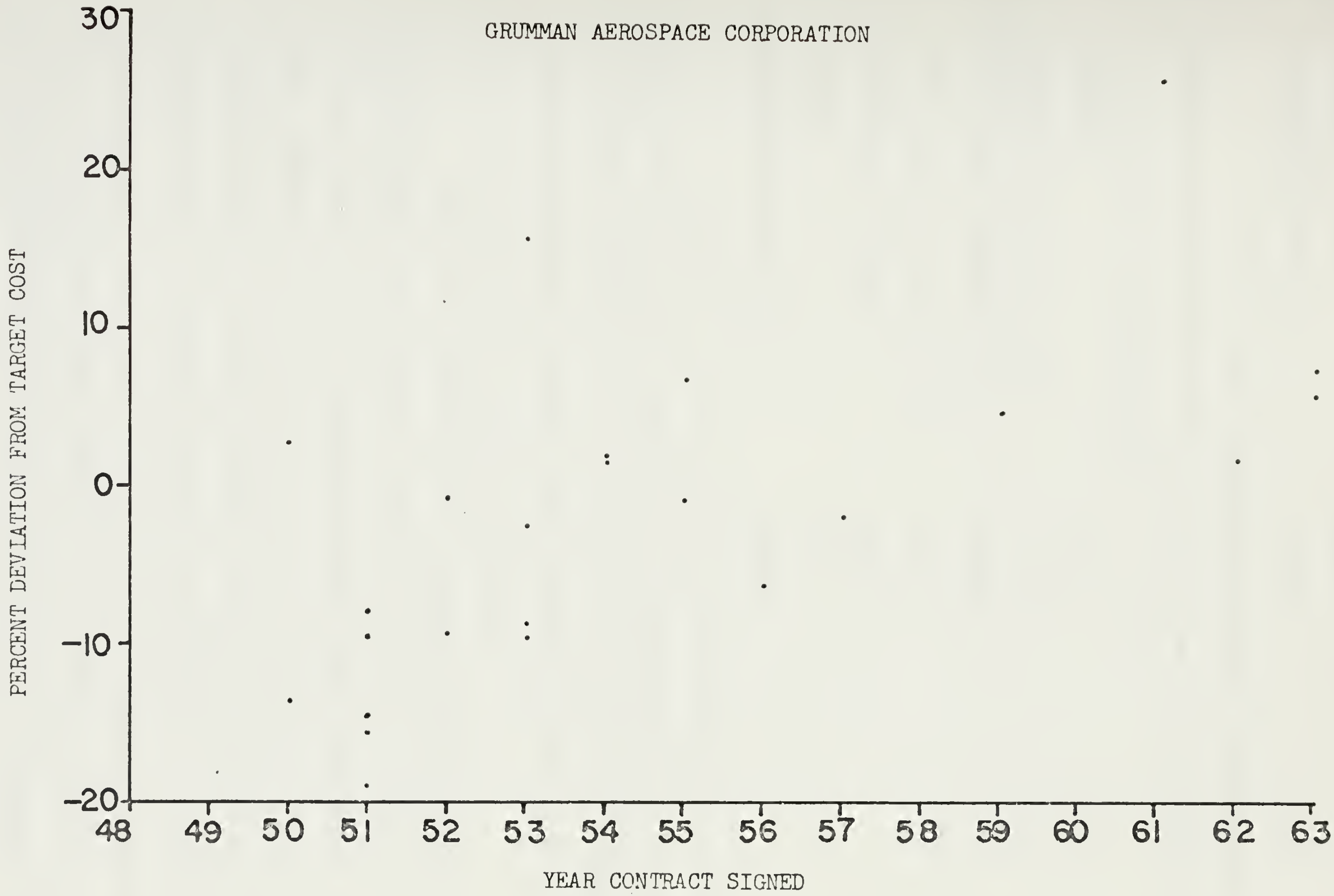
GRUMMAN AEROSPACE CORPORATION
PERCENT DEVIATION FROM TARGET COST
30
20
10
0
-10
-20
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
YEAR CONTRACT SIGNED

Figure 1

Std. Error of Estimate	± 8.20
F-value	14.54
Probability that $b_9 \neq 0$	0.995

A similar linear regression of percent deviation versus the number of contracts signed the same year as the observed contract (X_8) was performed. The results were:

Intercept	9.68
Regression Coefficient (b_8)	-0.716
Correlation Coefficient (R)	0.667
Determination Coefficient (R^2)	0.45
Std. Error of Estimate	7.88
F-value	17.65
Probability that $b_8 \neq 0$	0.995

Because of the predictive power displayed by variables X_8 and X_9 in the case of the Grumman data, the author was moved to attempt to generate a Grumman model for percent deviation from target cost. This was done using the stepwise linear regression routine previously used for the same purpose with all of the data.

One of the uncertainties of stepwise regression is that the resulting value of the multiple correlation coefficient (R) may vary depending upon the first independent variable used. This uncertainty becomes particularly important when the list of independent variables considered contains two rather powerful predictor variables (X_8 and X_9) which are closely correlated (correlation of X_8 with X_9 = -0.838). In this case, the routine picks the most powerful variable and the other is more or less automatically eliminated from further consideration by its high correlation with the first variable used. To eliminate this

uncertainty of result, the stepwise regression was conducted with all independent variables free and then another stepwise regression was conducted in which the routine was forced to start with the previously unused variable. The results of these two stepwise linear regressions were:

(1) All Independent Variables Free

Regression Coefficient	Value	F-ratio	Probability $b_i \neq 0$
b_8	-0.688	19.74	0.995+
b_{10}	8.948	3.72	0.900+

Intercept	4.95
Correlation Coefficient (R)	0.752
Determination Coefficient (R^2)	0.57
Std. Error of Estimate	$\pm$7.14
F-ratio for the Regression	13.646
Probability all $b_i \neq 0$	0.995

(2) Routine Forced to Use X_9

Regression Coefficient	Value	F-ratio	Probability $b_i \neq 0$
b_1	0.101	2.26	0.750+
b_3	-10.8	12.86	0.995+
b_9	2.74	39.19	0.995++

Intercept	72.22
Correlation Coefficient (R)	0.82
Determination Coefficient (R^2)	0.66
Std. Error of Estimate	$\pm$6.43

F-ratio for the Regression	13.20
Probability all $b_i \neq 0$	0.995++

b. Lockheed

A plot of percent deviation from target cost versus the year the contract was signed for Lockheed (Figure 2) also revealed an interesting pattern. This pattern looked to the author like a sine wave. The independent variable for a linear regression was determined to be a function of the year the contract was signed ($X = \cos(360/12 (X_9 - 2) + 90)$) where the period of the wave was approximated as 12 years. The regression equation used was then % deviation = a + bX. The results of this regression and an ordinary linear regression for comparison were:

	$X = \cos(360/12(X_9 - 2) + 90)$	$X = X_9$
Intercept (a)	-2.3	-4.31
Regression Coefficient (b)	2.4	0.272
Correlation Coefficient (R)	.387	0.222
Determination Coefficient (R^2)	0.15	.05
F-value	4.928	1.457
Probability that $b \neq 0$	0.950	0.750

c. Other

Plots of percent deviation versus year for the other contractors displayed no discernable significant pattern.

Linear regressions of percent deviation versus number of contracts signed that year for the other contractors failed to reach the probability that $b \neq 0$ required for significant statistics (0.950).

LOCKHEED AIRCRAFT CORPORATION

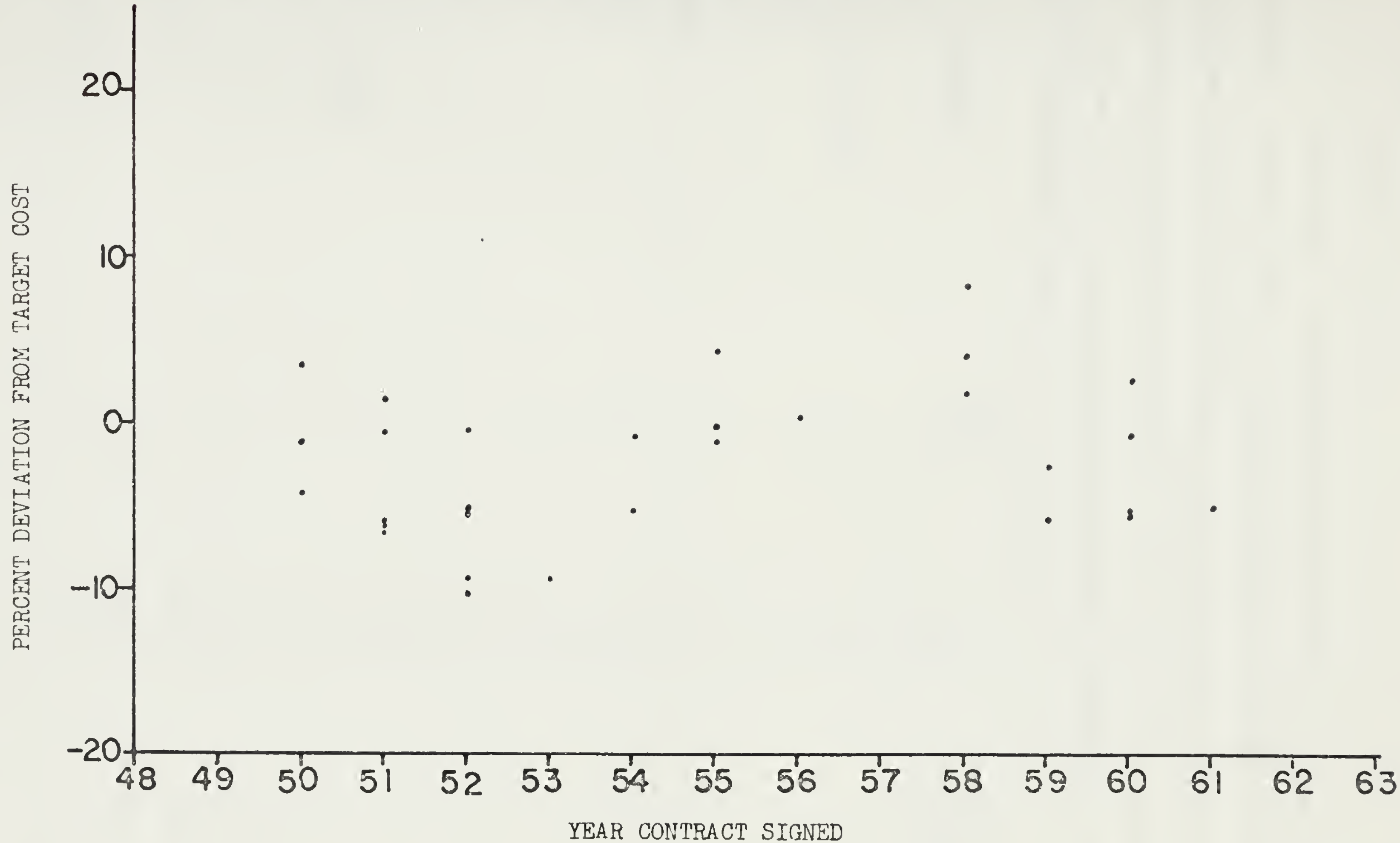

Figure 2

B. ANALYSES OF VARIANCE AND SCHEFFÉ COMPARISONS

1. By Contractor

a. Analysis of Variance

Preparatory to conducting a one-way analysis of variance by contractor, the data field was reduced by removing the data for those contractors who had only one contract during the period. Each remaining contractor was designated as a treatment level of the factor, contractor. The sample size , mean percent deviation and standard deviation for the contractors (treatments) analyzed were:

Treatment	Sample Size	Mean	Standard Deviation
Beech	4	-2.78	12.21
Ling-Temco-Vought	10	0.59	9.38
Convair	10	-.37	8.99
Douglas	24	-2.11	9.25
Goodyear	6	-4.70	4.75
Grumman	24	-1.99	10.34
Hiller	8	7.64	8.18
Kaman	6	11.95	12.97
Martin	7	-6.30	7.35
McDonnell	6	4.95	11.82
North American	13	-1.75	6.07
Vertol	3	-4.77	5.48
Ryan	6	-2.33	3.60
Sikorsky	9	-6.82	4.60
Bell	2	4.65	8.84
Lockheed	30	-2.50	4.53

Treatment	Sample Size	Mean	Standard Deviation
Philco	2	14.25	17.47
Raytheon	3	-8.20	13.17

The F-ratio for this analysis of variance was 2.76 which allows rejection at a significance level of .005 of the hypothesis that the treatment samples all came from the same population. That is, one may be .995 confident that the treatment samples did not all come from the same population. However, the analysis of variance does not allow selection of any treatment as being significantly different from another. That is, one may not say that Philco with a mean percent deviation from target cost of 14.25 is significantly different from Raytheon with a mean percent deviation of -8.20.

b. Scheffé Comparison

To continue the investigation started in a. above, a Scheffé Comparison test was conducted using the F-value corresponding to the level of significance designated by statisticians as statistically significant, .05. The result was that none of the treatments (contractors) were different from any of the others at that level. The level of the comparison was successively reduced until differences began to appear. At a significance of 0.25 there was still no statistical differences between contractors. At a significance level of 0.50 differences began to emerge, but this is the statistical equivalent of a toss-up, i.e., these differences were no more likely to exist than to not exist.

2. By Type of Item Purchased

a. Analysis of Variance

To determine whether percent deviation from target cost were significantly different among different types of items purchased, a one-way analysis of variance was conducted in which the type of item was the factor and the treatment levels were the seven different types of items purchased which have been previously identified. The mean percent deviations, sample sizes, and standard deviations obtained were:

Treatment	Sample Size	Mean	Standard Deviation
Utility Airplanes	21	-4.44	7.22
Combat Airplanes	88	-0.98	8.52
Missiles	19	-2.14	10.82
Blimps	6	-4.70	4.75
Helicopters	28	2.37	11.08
Drones	8	1.08	7.47
Airborne Avionics	8	-1.18	9.50

The F-ratio for this analysis was 1.45 which corresponds to a level of between .25 and .10. This level is insufficient to allow rejection of the hypothesis that the treatment samples came from the same population, therefore further investigation using the Scheffé comparison test was not justified.

3. Individual Contractors by Year the Contract Was Signed

Three of the contractors were selected for separate analyses of variance on the basis that they had more than 20 contracts during the period. The year the contract was signed was selected as the factor for one-way analyses to determine if any sharp changes in

contractor policy or environment had occurred which would not have been identified when that factor was used as a linear regression variable.

a. Lockheed

(1) Analysis of Variance. Lockheed started and completed 30 contracts during the period of the data. The Lockheed data were pooled into two-year treatments to provide adequate numbers of observations in each cell and the odd contract was dropped. The sample sizes, means and standard deviations which resulted were:

Treatment	Sample Size	Mean	Standard Deviation
1949 & 1950	3	-0.73	3.92
1951 & 1952	10	-4.99	3.83
1953 & 1954	3	-5.37	4.30
1955 & 1956	4	0.68	2.42
1957 & 1958	3	4.67	3.25
1959 & 1960	6	-3.07	3.38

The F-ratio for this analysis was 4.54 which allows rejection of the one-population hypothesis at a significance level of .005. Because the hypothesis was rejected at a very significant level, the Scheffé comparison was performed.

(2) Scheffé Comparison. A Scheffé comparison was conducted using the F-value corresponding to a significance level of .05, "statistically significant". The pooled years 1951 and 1952 were determined to be significantly different from the pooled years 1957 and 1958. However, in view of the sine-wave pattern exhibited by the Lockheed data when plotted against the year the contract was signed

(paragraph IV.2.b), this appears to be a comparison of the peak of the wave with the valley.

b. Grumman

(1) Analysis of Variance. Grumman started and completed 24 contracts during the period of the data. These data were pooled into three-year treatments and a one-way analysis of variance was conducted. The samples sizes, means and standard deviations which resulted were:

Treatment	Sample Size	Mean	Standard Deviation
1949 - 1951	6	-10.33	7.52
1952 - 1954	8	-1.59	8.43
1955 - 1957	4	-0.70	10.22
1961 - 1963	4	10.65	10.65

The F-ratio for this analysis was 5.07 which allows rejection of the one-population hypothesis at the .025 level.

(2) Scheffé Comparison. The Scheffé comparison was conducted using an F-value corresponding to a significance level of .025. This level falls between "statistically significant" and "statistically very significant". Pooled years 1949 - 1951 were found to be significantly different from pooled years 1961 - 1963. This finding agrees with the significant positive trend identified in the Grumman data in paragraph IV.2.a.

c. Douglas

Douglas started and completed 24 contracts during the period under investigation. These data were pooled in two-year treatments and a one-way analysis of variance was performed. The sample sizes, means, and standard deviations from this analysis were:

Treatment	Sample Size	Mean	Standard Deviation
1949 & 1950	3	-1.17	2.44
1951 & 1952	8	-3.14	12.23
1953 & 1954	6	-3.20	10.00
1955 & 1956	2	3.45	5.59
1957 & 1958	2	-8.00	9.05
1959 & 1960	2	-1.80	2.26

The F-ratio for this analysis was 0.29 which is not statistically significant. No Scheffé comparison was conducted in this case.

V. CONCLUSIONS

The most that can be gained from the results of the analyses presented in Section IV alone are statistical inferences. Firstly, no cause/effect relationships can be established by statistical analysis. Secondly, failure to reject a one-population hypothesis or a $b_i = 0$ hypothesis does not prove that those hypotheses were true. It merely states that with the statistical methods and standards employed and the data analyzed, it was not possible to reject those hypotheses. Nevertheless, the author will draw conclusions on the basis that the statistical analysis combined with the author's intuition and knowledge, and other sources of information present a reasonable case, lacking opposing evidence, for the conclusion drawn. The reader who is unwilling to accept the author's conclusions on such a basis is free to draw his own or none from the statistical evidence presented in Section IV of this paper.

A. CONTRACT PARAMETERS' EFFECT ON DEVIATION FROM TARGET COST

1. Parameters Which Have a Significant Effect on Contract Cost Outcome

a. All contractors

(1) Length of the period of contract performance - Deviation from target cost varied positively with the length of performance of the contract at the rate of approximately 1.5% per year. The author's hypothesis about this variable was supported by the data. In view of the length of time available for changes in both requirements

and details in a multi-year contract, and the general inflationary trend in this country since World War II, this is not a surprising conclusion.

(2) Target profit - Deviation from target profit varied negatively as target profit at a rate of more than 1% per percent target profit increase. The conclusion that may be drawn here is: depending upon the sharing ratio, it may be less expensive in terms of total price for the government to be relatively generous in target profit. For example, in a contract with a 10% target profit and a sharing ratio, a one percent increase in target profit may be expected to result in a 1.3% decrease in realized cost and a 0.3% decrease in actual price. As the variations in target profit in the data were small, one would not be justified in making large target profit adjustments on this basis. The author's hypothesis with respect to target profit was not supported by the statistical analysis. The author has no intuitive explanation to offer for this rather surprising result.

(3) Ceiling price - Deviation from target cost varied positively with ceiling price at the rate of approximately 0.4% per percent increase in ceiling price. The author's hypothesis with respect to the effect of ceiling price was supported by the analysis.

(4) The number of contracts signed in the Navy aircraft and missile field during the same year as a particular contract - Deviation from target cost varied negatively as the number of contracts signed. This variable was chosen as a measure of the degree of competition (or pressure) felt by a contractor when negotiating a particular contract. The theory being that as the total number of contracts in the Navy aircraft and missile field becomes smaller, the importance in

terms of prime contractor survival of obtaining a particular contract goes up. Reaction to this pressure in the form of acceptance of an unrealistically low target cost does not require that the contractor knowingly buy in. All he has to do is to relax a little his normal degree of resistance to engineering optimism, etc. The author's hypothesis regarding the effect on deviation from target cost of reduced number of available contracts is supported by the analysis. One is reminded of the apocryphal story of the gambler who took part in a game he knew to be rigged against him because "It was the only game in town." The story may be apocryphal but its message is valid.

(5) The year the contract was signed - The deviation from target cost varied positively as the year the contract was signed. The author's hypothesis in this regard was supported by the analysis. The only explanation that occurs to the author for this result of the analysis is a gradual change with time of contractor policy toward cost overruns. It is significant that although the year the contract was signed and the number of contracts that year are rather closely related, they both are significant in the regression equation. Thus, one may not say that the positive effect of the year the contract was signed was simply a result of the intensified competitive atmosphere.

(6) The product of the target cost and the number of items procured - Deviation from target cost varied negatively as the product of target cost and the number of items procured. The author's statistical reasoning concerning a combination of two unrelated variables which singly were insignificant was supported by the appearance in the regression equation of this variable. The author was then faced with the necessity of attempting an explanation of this statistical

fact in logical terms. This, he has been unable to do. Nevertheless, the predictive power of this variable remains whether or not the author can state a logical explanation.

b. Individual Contractors

(1) Grumman. Deviation from target cost in the case of Grumman contracts showed a strong reaction to both the year the contract was signed and the number of like contracts signed that year. The year the contract was signed alone accounted for 40% of the variation in Grumman's deviation from target cost. When all of the original variables and the two transgenerated ones were considered in a stepwise linear regression on the Grumman data, deviation from target cost varied negatively with the number of contracts signed and positively with the unit cost of the item procured (target cost/number of items procured). Together, these two variables accounted for 57% of the variation in Grumman's deviation from target cost. These two variables have approximately twice the predictive power in Grumman's case than the variables included in the regression equation for all contractors. No conclusions were drawn from the second regression (routine forced to use X_9 per IV.A.2.a) because one of the variables included by the stepwise linear regression routine had only a .75 probability that its regression coefficient (b_1) was not equal to zero.

Grumman's heavy dependence on Navy airframe contracts goes a long way toward explaining this result. The complexity involved in high unit cost items also provides a reasonable explanation of the positive variation of deviation from target cost with unit cost. The implications of this predictive equation with respect to the current cost overrun problems associated with the F-14 program are obvious if

one allows a valid comparison between non-total package procurement contracts and total package procurement ones.

(2) Lockheed. The impression that Lockheed's deviations from target cost were cyclical with time was supported by the linear regression which used a cosine function of X_9 as the independent variable. As compared to a linear regression using X_9 as the independent variable, the correlation coefficient, determination coefficient and F-ratio were materially improved. The extent that the cosine equation accounts for the variation, 15%, Lockheed deviation from target cost oscillated about a level of -2.3% with an amplitude of 2.4%. Since the cyclical pattern does not occur when deviation from target cost is plotted against the number of contracts signed that year, one is tempted to postulate a cyclically varying management policy toward cost estimation or negotiated target cost. This theory would involve a more optimistic view of probable costs that is tempered as the results of the optimism begin to be apparent and then a shift back toward optimism as the results of relative pessimism begin to surface.

(3) Lockheed and Grumman. Although the analysis of variance conducted using the contractors as treatment levels provided no statistical basis for significant difference among contractors, the Lockheed and Grumman patterns of deviation from target cost were markedly different from the other contractors when plotted against the year the contract was signed. In both, trends over time were apparent. These time trends should be considered when negotiating contracts with two contractors. That is, Grumman's tendency to underestimate or accept unrealistically low target costs had steadily increased while Lockheed

oscillated about a rather favorable level of deviation from target cost (-2.3%).

2. Statistically Insignificant Parameters

Parameters which are unexpectedly insignificant can be as informative as those that prove to be significant. Accordingly, they will be given as much attention as were the significant parameters.

a. Sharing ratio - The theory of cost-incentive contracting rests upon the supposed influence a share of underrun or overrun will have upon a contractor's cost-associated decisions. Further, multiple incentive contracts depend upon an assumption that the various performance and schedule incentives will be balanced against the cost incentive in the contractor's tradeoff decisions to the advantage of the contractor and the government. If the cost incentive proves to be ineffective and the results relatively unpredictable, then the supposed benefits of multiple incentive contracting must also be seriously doubted. This is a point of considerable importance since the additional cost of administering a multiple-incentive contract may be largely wasted.

In the case of the 177 Navy aircraft and missile contract examined in this thesis, sharing ratio is an insignificant parameter with respect to association with cost overrun/underrun (probability the $b_4 \neq 0$ between 0.50 and 0.75). This is not a wholly surprising outcome in that a Rand study of 427 Air Force contracts resulted in a conclusion that the value of the sharing ratio was an insignificant parameter [ref. 5]. Because the Air Force contract data contained both cost incentive and cost reimbursable contracts, Rand was also able to conclude that although the value of the sharing ratio was

insignificant, deviations from target cost were significantly more positive in cost-reimbursable contracts than in cost-incentive contracts. An explanation which might be made is that the existence of the incentive completely unrelated to the value of the sharing ratio might influence contractor performance of the contract. A more likely explanation is that the use of an incentive contract in a particular case may have resulted in an upward shift in the negotiated target cost [ref. 6]. Since cost-reimbursable contracts encourage contractors to grossly understate expected costs to ensure receiving the contract, cost-incentive contracts may have the benefit to the government of preventing grossly understated expected costs.

In any case, the analysis contained herein in no way supports the theory that sharing the cost risk with the contractor significantly effects his efficiency of performance of the contract or influences him in cost-associated decision making.

b. Target cost/Unit target cost - Neither target cost nor unit target cost were significantly associated with deviation from target cost. Some attractively logical hypotheses regarding these parameters, e.g., that lower unit cost should be associated with more negative deviation from target cost because of economies of scale and the learning curve. That is, one would suppose that the expected positive deviation from target cost would be higher in a $100 M contract for 100 items (unit cost of $1 M) than a $100 M contract for 10,000 items (unit cost of $10,000). That attractive theory must be allowed to wither for lack of empirical support. However, one might consider the possibility that contractors depend too heavily on economies of scale, etc., in their cost estimates, or that the discontinuities in production frequently resulting from the annual nature of defense funding may tend to

prevent gaining the cost advantages of economies of scale or the learning curve.

c. Number of items - Similar arguments to those applied to unit cost could be applied to the number of items, i.e., the larger the number of items the more negative the deviation from target cost, but such arguments were similarly unsupported by the data.

d. Contractor - No statistical significance could be attached to the contrasts among contractors. However, if faced with a choice between Kaman (mean percent deviation from target cost = 11.95, standard deviation = 12.97) and Vertol (mean percent deviation from target cost = -4.77, standard deviation = 5.48) other things being essentially equal, one would be foolish to choose Kaman on the basis that the difference in contract experience with the two contractors was not statistically significant.

e. Type of item - Although the items procured under the 177 contracts in the data differ radically in physical terms, they were all procured by the same agency, NAVAIRSYSCOM, to aviation standards. No statistically significant differences were found among them. The means differ noticeably but the associated variances are too large to allow statistically significant differences among the means.

B. OVERRUN/UNDERRUN PREDICTIVE MODEL (ALL DATA)

The following discussion refers to the predictive model reported in paragraph IV.A.1.a,

$$\text{Percent deviation from target cost} = -42.4 + 0.128X_1 - 1.68X_3 + 0.397X_5 - 0.297X_8 + 0.823X_9 - 0.00004X_{11} .$$

1. Amount of Variation Explained

The power of the model to explain the variation in the analyzed data, approximately 25%, was disappointingly low. Its power to predict future contract outcomes, of course, is unknown but should not be expected to improve over that for the data from which it was generated. Still, a model of this nature might give some inkling of the outcome of a particular future contract. It is probably better than an assumption that the contract outcome in terms of actual cost will be equal to the negotiated target cost. The argument here, albeit a weak one, is that the model is probably better than no consideration of the historical realities of contract outcome. But, of course, past realities may or may not be similar to future realities. As is the case with many mathematical models, most of the value of this model is in understanding the relationships or lack of them among the variables.

2. Standard Error of Estimate

The large standard error of estimate, approximately 8%, is in keeping with the low amount of variation accounted for. The model as a valid predictor of future contract outcome is largely useless.

C. THE RELATIONSHIP OF TARGET PROFIT TO OTHER CONTRACT PARAMETERS

Three other contract parameters were found to be statistically related to negotiated target profit. They were sharing ratio, ceiling price, and number of items procured. Together these variables follow the previous trend, that they account for little of the variation of target profit. This discussion will concern the individual variables.

1. Sharing ratio - Target profit varied positively with sharing ratio. The theory that the contractor who bears the larger financial risk should be rewarded with a higher target profit appears to be

supported in this case. A similar conclusion was reached by Rand in its study of 427 Air Force contracts [ref. 7].

2. Ceiling price - The negotiated target profit varied negatively with ceiling price. A higher ceiling price reduces the contractor's financial risk by causing the point of total assumption (PTA) to occur further from the target cost. All other things being equal, the further the PTA is from the target cost, the lower the probability of the contractor finding himself in the position of paying excess costs out of his own pocket, dollar for dollar. Again, the lower the financial risk, the lower target profit, and vice versa.

3. Number of items procured - The target profit varied positively as the number of items procured. No explanation for this phenomena was apparent to the author.

D. SUMMARY OF CONCLUSIONS

The statistical inference really worthy of note in this thesis is the repeated failure of empirical evidence to support the supposed effectiveness of the sharing ratio. Since the cost incentive is the cornerstone of incentive contracting and incentive contracting is in extensive use today, it is a little disconcerting to find no empirical evidence to support it, i.e., percent deviation from target cost is not statistically related to the sharing ratio. It would seem prudent, lacking supportive evidence, to not place such dependence on incentive contracting to influence efficient contractor performance. Faith in an unprovable principle has its place in religious matters but not, in the author's view, in matters of economy and national defense.

APPENDIX A

COMPUTER CODE FOR THE SCHEFFÉ COMPARISON (S-TEST)

The following computer code is written in FORTRAN G and was used on an IBM 360 computer.

```
C       PROGRAM TO TEST FOR SIGNIFICANT DIFFERENT IN ANOVA TREATMENTS
C       USING SCHEFFE METHOD
        READ (5,10) NGROUP,SQUARE, FVAL
     10 FORMAT (I2,2F10.4)
        DIMENSION ISAMSZ(30),ERMEAN(30),ERTOT(30)
        DO 15 J=1,NGROUP
        READ (5,12) ISAMZ(J),ERMEAN(J)
     12 FORMAT (I2,F12.5)
        ERTOT(J)=ISAMSZ(J)*ERMEAN(J)
     15 CONTINUE
        JGROUP=NGROUP-1
        A=(JGROUP*FVAL)**0.5
        DO 200 I=1,JGROUP
        DO 150 J=I,JGROUP
        K=J+1
        COMP=ISAMSZ(K)*ERTOT(I)-ISAMSZ(I)*ERTOT(K)
        IF (COMP.GE.0) GO TO 152
```

```
      COMP=-COMP
  152 VARCOM=ISAMSZ(K)**2*ISAMSZ(I)*SQUARE+ISAMSZ(I)**2*ISAMSZ(K)*SQUARE
      AVAR=A*VARCOM**0.5
      WRITE (6,110) I,K,COMP,AVAR
  110 FORMAT ('0','GROUP',2X,I2,4X,'GROUP',2X,I2,4X,'COMPARISON=',
     1F12.4,4X,'AVARIANCE=',F12.4)
      IF (COMP.LE.AVAR) GO TO 150
      WRITE (6,120) I,K
  120 FORMAT ('0','**** GROUP',1X,I2,1X,'IS SIGNIFICANTLY DIFFERENT FROM
     1 GROUP'1X,I2,'  ****')
  150 CONTINUE
  200 CONTINUE
      STOP
      END
```

Explanation of Input Variables

NGROUP	Number of treatment groups (levels)
SQUARE	Within-groups mean square value from preceeding ANOVA
FVAL	F ratio for desired level of significance of the comparison based on between-groups and within-groups degrees of freedom from the ANOVA. Example: If the between groups degrees of freedom are 3 and the within-groups 18, and the desired level of test is .025, the value of FVAL is 3.9539.

$(F_{3,18;.025} = 3.9539)$.

ISAMSZ(J) The sample size in the jth treatment group

ERMEAN(J) The mean of the jth treatment group

Limitations

The program as contained herein is limited to: (1) no more than 30 treatment groups and accompanying values of ISAMSZ and ERMEAN, and (2) comparison of each treatment group with each of the other treatment groups.

Sample Output

```
                    .
                    .
                    .

GROUP  1   GROUP  4   COMPARISON=   493.3989   AVARIANCE=   436.9731
**** GROUP  1  IS SIGNIFICANTLY DIFFERENT FROM GROUP  4  ****
GROUP  2   GROUP  3   .............................................
```

LIST OF REFERENCES

1. Scherer, F.M., "The Theory of Contractual Incentives for Cost Reduction," The Quarterly Journal of Economics, v. 78, p. 267, May 1964.

2. Scherer, F.M., "The Theory of Contractual Incentives for Cost Reduction," The Quarterly Journal of Economics, v. 78, p. 262, May 1964.

3. Rand Corporation Report RM-5120-PR, Cost Incentives and Contract Outcomes: an Empirical Analysis, by Irving N. Fisher, p. 14, September 1966.

4. McCall, J.J., "The Simple Economics of Incentive Contracting," The American Economic Review, v. 60, number 5, p. 845, December 1970.

5. Rand Corporation Report RM-5120-PR, Cost Incentives and Contract Outcomes: an Empirical Analysis, by Irving N. Fisher, p. 38, September 1966.

6. Rand Corporation Report RM-5120-PR, Cost Incentives and Contract Outcomes: an Empirical Analysis, by Irving N. Fisher, p. 43, September 1966.

7. Rand Corporation Report RM-5120-PR, Cost Incentives and Contract Outcomes: an Empirical Analysis, by Irving N. Fisher, p. 26, September 1966.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
3.	Associate Professor Michael G. Sovereign Code 55Zo Department of OR/AS Naval Postgraduate School Monterey, California 93940	1
4.	Professor P.A.W. Lewis Code 55Lw Department of OR/AS Naval Postgraduate School Monterey, California 93940	1
5.	Mr. M.E. Biciocchi Code MAT 022B Headquarters, Naval Material Command Washington, D.C. 20360	1
6.	Assistant Professor D.R. Whipple Code 55Wp Department of OR/AS Naval Postgraduate School Monterey, California 93940	1
7.	Department of OR/AS Naval Postgraduate School Monterey, California 93940	1

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

RIGINATING ACTIVITY (Corporate author) Naval Postgraduate School Monterey, California 93940	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

EPORT TITLE

A Statistical Analysis of Deviations from Target Cost in NAVAIRSYSCOMHQ Fixed-Price Incentive Contracts During the 1949 - 1965 Time Frame

SCRIPTIVE NOTES (Type of report and, inclusive dates)

Master's Thesis; March 1973

THOR(S) (First name, middle initial, last name)

Max Wayne Dixon

PORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
rch 1973	58	7

ONTRACT OR GRANT NO. ROJECT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

ISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

UPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Postgraduate School Monterey, California 93940

BSTRACT

This paper statistically analyzes 15 years of NAVAIRSYSCOMHQ fixed-price incentive contract experience in the aircraft and missile procurement field. The relation f basic contract parameters to contract outcome is explored through regression and nalysis of variance techniques.

The inferences arising from the statistical analysis are combined with other nformation to draw conclusions regarding incentive contracting. The most important f these is that there is no evidence that the negotiated sharing ratio has any nfluence on the contractor during the performance of the contract.

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Statistical Analysis						
Cost-Incentive Contracting						
Fixed-Price Incentive						
Sharing Ratio						
Aircraft and Missile Contracts						
Naval Air Systems Command						
Ceiling Price						
Target Profit						
Grumman						
Lockheed						

Thesis
D599 Dixon 143308
c.1 A statistical analysis
of deviations from target
cost in NAVAIRSYSCOMHQ
fixed-price incentive
contracts during the
1949-1965 time frame.